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ABSTRACT

This paper describes the improvement of a series of lab courses in electrical engineering at the University of Twente in Enschede, the Netherlands. Five differing courses of lab classes (measuring instruments and network analysis, basic digital circuits, basic circuits of electronics, electronic functions, and physics measuring methods and systems) seemed unrelated to students, although in all classes one of the main objectives was to learn to experiment in a systematic way. Faculty, teaching assistants, and administrators in the department seemed unable to change the situation. A systematic approach to change was developed and implemented that focused on four aspects of professional behavior: rational use of knowledge; personal directed interaction with people; operationally obtaining some results; and fulfilling conditions by provision with means. This led to changes in the procedures used in lab write-ups and student notebooks, the development of a general lab guide, and regular meetings among faculty and teaching assistants in the five courses. An appendix contains the framework for lab write-ups. (MDM)

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A Model of Professional Behavior and a Model of Common Aspects.

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Abstract

Five differing courses of lab classes seemed unrelated to the students, although in all classes one of the main objectives was to learn to experiment in a systematic way. Faculty, teaching assistants and administrators of the department could not change this situation. A systematic approach for change has been followed that can be described with the aid of two coupled instruments. First a model of four aspects of professional behavior has been used: rational use of knowledge, personal directed interaction with people, operationally obtaining some results, and fulfilling conditions by provision with means. Second, a method for investigation serving as a model of the common factor in the courses was developed by the "professionals". Results are: a general lab guide, logbooks of students reflecting the method in all five courses, regular meetings of faculty and t.a's in several course, and regular meetings of faculty of all five courses.

Introduction

Students often complain that curricula at university level show a lack of coherence. Each class forms a course on his own that can be mastered separately from others. Of course, concepts and skills learned in one course, often have to be used in a next one, and also student's academic abilities show some progress. Somehow this is not enough for many students. The progress is not explicitly evaluated, either.

In the department of Electrical Engineering of the University of Twente systematics are sought to change this situation. This means that instruments are investigated on two levels: the level of changing the behavior of staff members, and the level of perceptible coherence in the content of several courses.

In our department several theoretical courses are accompanied by lab classes. Such lab classes form a course of their own, rather independent of the theoretical course, with differing objectives, and results uncorrelated with the theoretical course. Other laboratory courses run without a theoretical course. The case reported about concerns five courses of lab classes in one academical year: Measuring Instruments and Network Analysis (19 half days), Basic Digital Circuits (6 half days), Basic Circuits of Electronics (10 half days), Electronic Functions (10 half days) and Physics Measuring Methods and Systems (12 half days, no theoretical course).

In the past students complained that each new course of lab classes had nothing to do with the prior ones. Teaching assistants (t.a.'s) complained that often theoretical concepts and instruments from an earlier course had to be used but were "already forgotten". Faculty responsible for the lab courses blamed students for not being able to apply knowledge from earlier courses, and for not finishing lab classes in time. T.a's blamed students for not knowing how to tackle new assignments or not be able to explain what they were doing and why.

Typical interventions did not work. Administrators could not get faculty to work on this issue. Earlier interventions by an educational consultant failed. No description of a change as desired could be traced in literature, nor a coherent set of procedures for such a change.

The approach followed to change this situation should be described in a systematic way in order to generalize to other courses. Our questions therefore are:

1. How can the specific way of change be described in a general way, and how did this work out?
2. What are the results of this change in terms of behavior of faculty?

3. How can the content of several courses be made perceptibly coherent for students?
4. What are the results of coherence in the courses?

The question how the conceptual framework is translated into specific interventions, will be left aside in this paper, because this requires an independent observer.

Perspective

Models for innovation in education serve different goals. One is to model the actions and phases in renewal (see e.g. Havelock, 1973). Another one is to model the client. We focus on the last one because in our research-oriented university environment, faculty are very independent and educational organization is anarchical and non-hierarchic (cf. Birnbaum, 1988).

The idea behind this approach is that faculty responsible for the courses, are professionals in their field of knowledge. This expertise should be used, and their responsibilities should be considered.

Faculty often are not interested to learn other educational techniques than they already apply and prefer. They are usually not qualified as a teacher. They are only indirect responsible for students' results, because it is the task of the t.a.'s to instruct the students and to criticize and grade their results, and it is the responsibility of the student to work hard (or not).

Faculty are responsible for the content of the course, the scientific aspects of the formulation of the assignments, for the organization of the classes and assessments, and for the training of the t.a.'s.

The systematics of this approach can be described with a model of four aspects of professional behavior. On the dimension of internally-externally oriented action, we distinguish rational use of knowledge (intellectual behavior) and operationally obtaining results (pragmatic behavior). On the dimension subjective feelings-objective procedures we distinguish personal directed interaction with people (social behavior) and fulfilling conditions by obtaining means or instructions (instrumental behavior) (Van Delden, 1992).

Influencing professionals thus is possible in four ways: rationally explaining and discussing issues, personally getting people involved, operationally trying to get results and conditionally charging people and providing means.

Often influencing faculty is done in one or two of these ways: an instructional consultant has e.g. his preference. An administrator convenes faculty for a meeting and asks them to do something only (personal aspect). The ideas about how to improve the situation are taken from literature or experience elsewhere (conditional).

Interventions in groups of professionals are probably more effective if they contain all four elements. In this approach, administrators, faculty, t.a.'s, and the educational consultant (the author) have responsibilities of their own that can be distinguished although not separated. The change started in the following way.

The author has got a tenured position as departmental instructional consultant. A questionnaire and interviews revealed that one of the main objectives of each course was to learn to experiment in a systematic way. This common factor was taken as a starting point.

Influencing the faculty was done by convening the staff members responsible for the courses, adding the educational consultant and thus creating a group (personal aspect), responsible for attunement of the five lab courses, without a formal position (conditional). This group had to find a way to make the courses more coherent. Issues were: what is experimenting in a systematic way in Electrical Engineering? (rational) and, how can we get the students to learn that? (operational).

Method of research

Because the author observed and participated in the meetings, he was able to describe the way of change and the change in behavior of faculty. He also influenced the outcome of the meetings by preparation and active participation, and by telling the administrators what to do.

An analysis of the change process was carried out according to the model of Van Delden (l.c.).

The way coherence is made perceptible for students can be observed from the outcome of the change process.

The results of coherence are investigated in two ways. The logbooks of the students were used

to assess their performance by the t.a.'s. The remarks of t.a's about students' performance give a qualitative indication of the results.

Secondly, a special assignment in each course of lab classes was analyzed quantitatively to assess longitudinal development of the students as individuals and as groups. The procedure for this was as follows.

In three of the laboratory courses an assignment was selected in which student could show knowledge and skills not explicitly asked for. About ten percent of the logbooks were used to find the dimensions on which could be scored. For each dimension a specific question was formulated and categories of answers were defined. In this way scoring could be made quantitative.

An example for the dimension theory is:

1. How applies the student theoretical knowledge when not asked to? with the categories:

a. Hypothesizing: the student formulates a new hypothesis or investigation to explain the difference between measurement and calculation.

b. Integrated: the student derives or calculates a quantitative expectation on the basis of theory or earlier assignments.

c. Not integrated: the student makes correct qualitative statements that do not lead to a clear expectation.

d. Intuitive: the student gives an incomplete but not incorrect reasoning, while the theory needed to make the statements complete has not yet been treated in a theoretical course.

e. No reasoning/ error

Other dimensions are:

2. How is the theoretical input represented in the logbooks?
3. What method of measurement/construction is used?
4. How are the results displayed?
5. In what way draws the student a conclusion?
6. How is planning visible from the logbooks?
7. How did the students cooperate?

Results

The change worked out in the following way (question 1).

change

In stead of taking a method from elsewhere (e.g. Reif & St.John, 1979), or one used before 1992 in a different laboratory course (Tattje & Vos, 1995), the group developed a method for investigation by themselves (see appendix). After some discussions and attunements the method was accepted as a guideline for all five lab courses (rational aspect), starting from the academical year 1992/93.

It was agreed upon, that requirements for lab write-ups should draw the attention of the students to the systematics of experimenting. The t.a's should assess the logbooks, and comment and grade the results not only with respect to the content of the task, but also with respect to the systematics of investigation and planning of the work that should be visible from the logbooks. Training of the t.a.'s was considered necessary (operational) as were regular meetings of faculty and t.a.'s (personal).

A general lab guide was planned, containing the general guidelines for investigation and lab write-ups, and practical information common to several courses. Each faculty contributed some parts (personal, operational). The educational consultant wrote the general guideline (conditional). Distribution of the general lab guide was provided by the department, i.e. the educational consultant (conditional).

In each lab course the lab guides and some assignments were changed in accordance with the overall objectives accepted (operational).

Training of the teaching assistants was organized by the educational center of our university and/or the educational consultant (conditional). Especially the prescriptions for taking lab notes and thus aiding the students to learn the general method, got attention in the sessions of two half days each (preparation not included).

Meetings of t.a.'s and faculty (personal) to evaluate one or more lab class and to prepare the

next ones (operational) were organized by the educational consultant (conditional) in three courses. The educational consultant attended about 20 of these meetings, and 3 half days of training, in the academical year 1992/93.

These changes also created a change in the behavior of the people involved (question 2).

behavior

The regular meetings among faculty and the consultant created a team spirit. All want to continue this system of regular meetings. The same applies to the regular meetings among t.a.'s and faculty. New t.a.'s are now requiring such meetings from faculty.

Faculty better understand the problems of the t.a.'s, aiding and guiding the students through the lab courses. They become more inclined to instruct t.a's clearly in technical and pedagogical matters, in stead of telling them how the students should work.

Faculty responsible for the courses, are also adding references to the general lab guide on the initiative of themselves. Ways to improve the lab guides for the courses are planned: in one course by reanalyzing the formulation and objectives of the assignments, faculty rewriting the lab guide, in another by collecting the remarks and suggestions for improvement from t.a.'s, one of the t.a.'s reediting the lab guide.

coherence

The coherence of the courses is now made visible by the general lab guide, and the method of investigation and requirements for lab write-ups common to all courses (question 3).

Results of this change are visible in the logbooks of the students (question 4).

performance

All logbooks of the students reflect the method for investigation, that is common to the five courses of lab classes. In each new course they have to be reminded that the general method applies, but then they learn fast to apply this method in the new environment.

The number of students that apply knowledge in an integrated way, start at 31%, rise to 54% and finally to 79%. Non-integrated and intuitive use of knowledge start at 68% and 16% respectively, but disappear, about 5% remaining.

Representation of knowledge in the way of schemes rises.

The measurements are taken over a larger domain of the relevant quantity, frequency, and more points are measured, in later courses.

Double log graphs (Bode plots) are used by all students in the second course, starting at 9 percent in the first one.

All conclusions contain statements like "the results agree" form the beginning. In later courses the evaluation of results to clarify this statement becomes more often extensive (12- 28- 66%).

From the second course on planning follows the general framework in about 90% of the logbooks.

Cooperation between students is mostly visible when parts of the circuit can be made by different pairs of students. All students working in pairs, no cooperative division of tasks was visible from the logbooks of such a pair.

Drawing conclusions, planning of work, and proposing improvement of the experiments still require further attention.

Conclusions and discussion

It is concluded that tuning of five independent courses of lab classes in a difficult situation has been accomplished. The instrument, a method (for investigation) common to all courses, has been developed by faculty themselves. The systematic approach to change the faculty involved has been described by another instrument, a model for influencing professionals, generalizing over professionals at work.

It could be objected that the role of the educational consultant is an involved one: he does the work connected with the general lab guide and in fact takes informal responsibility for coherence of the courses. Indeed, he is now looking for opportunities to make the responsibility for coherence in lab courses a formal position in the department, that can be taken by anyone.

The result of the change is mostly that faculty are less concerned about how students should do

it, and more about prescriptions for write-ups that the t.a.'s should assess, comment and grade. This approach differs therefore from a typical one by an educational consultant, in that usually student behavior is investigated and faculty get directions how to better teach the students. The question: what opinions did the students have about the framework and the lab courses, was therefore not investigated.

This same approach seems possible for other courses of lab classes, especially those with assignments more oriented to technical design instead of investigation.

Another important outcome is that students now are taught what a scientific approach to practical problems involves -in stead of finding that out (or not) for themselves-, thus resulting in a better academic education. A method to evaluate this progress in academic skills looks promising.

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APPENDIX

Frame for Lab Write-up

In this table you find a framework for the content of logbooks in technical-scientific lab work. In case the order of steps is changed, point that out clearly and give your arguments.

I.	INTRODUCTION	State the problem
1.	General data	Title, lab assignment number, name, date, partner, etc.
2.	Introduction	What is exactly asked? Any constraints?
3.	Goal	Which (partial) problem is tackled? Any constraints?
4.	Expectations	What results have to fit? How accurately?
II.	ANALYSIS	Describe possible solutions
5.	Survey	Orientation, information gathering & processing, ideas, choices
6.	Formulae	Basic formulae and data
7.	Applicability	Constraints on the validity of the principle
8.	Modelling	Schematic, measuring scheme, physics, mathematics, simulation--model
9.	Processing	How are input and output data processed?
10.	Accuracy	How is accuracy of result determined?
III.	METHOD	Describe the solution procedure chosen
11.	Orientation	Learn to use tools, try out
12.	Method(s)	Describe method chosen, conditions
13.	Block scheme	Record setup, scheme, model, process
14.	Specifications	Of components, tools, software, equipment
15.	Symbols	Notation used, unequivocal
16.	Accuracy	Record accuracy of tools and equipment
17.	Influences	Influences of procedure or environment on results
IV.	EXECUTION	Execute the procedure chosen
18.	Orientation	Conclusions of tryout; first test
19.	Procedure	Describe how you are going to do it: choice of domain, number of points, etc.
20.	Execution	Realization, constructions, measurements, calculations, simulations
21.	Presentation	Tables, graphs, summaries
22.	Errors	Determine the errors in the results
23.	Significance	Relevant presentations of results
24.	Details	Deviations, disturbances, repetitions, etc.
V.	CONCLUSIONS	Final summary and discussions
25.	Comparison	Compare the results of two paths (see general scheme)
26.	Iteration	Not fitting: back to execution, method, analysis or statement of the problem Fitting/ time is over: continue
27.	Literature	Compare with results and methods of others
28.	Discussion	Is the problem solved? Defend model, method, execution
29.	Prospects	Possible improvements and further investigation
30.	Summary	Of final results, uniqueness of contribution

General scheme for investigation

The general framework for lab write-up applies especially to investigation problems. The problem is here that something is unknown. Investigation leads to reliable knowledge about the unknown. In these kind of problems always two (or more) paths of action can be distinguished that finally must join. The path can be measurement, calculation, simulation. In general, one can also add another independent measurement, calculation, simulation, reasoning, or observation.

Each path of action leads to some result, representing knowledge about the unknown. The results of both paths should fit to each other within the accuracy of the investigation. The conclusion: "the results agree" is an expression for the reliability of the knowledge. This can be modeled as a general scheme for investigation:

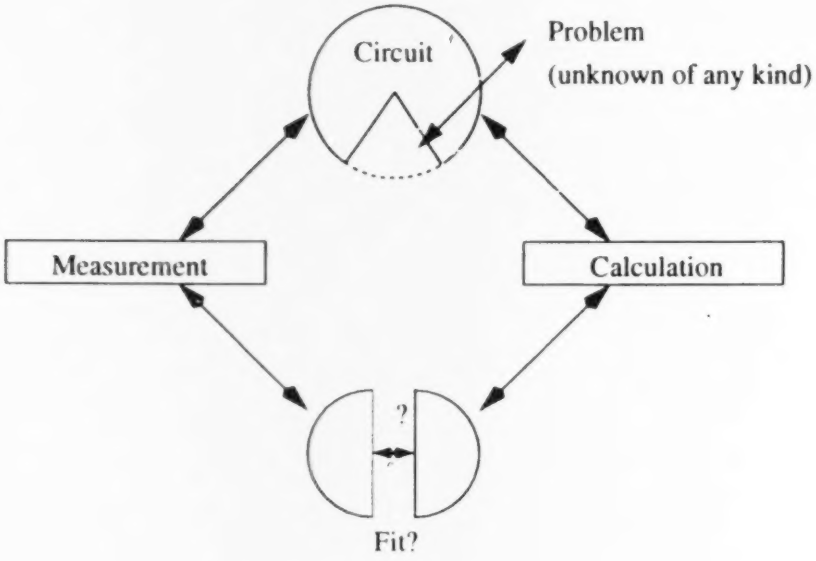

Fig. 1. General scheme for investigation

Some special features require attention. A measurement (or an observation) always involves an intervention in the object, the circuit. This intervention disturbs the quantity to be measured (or changes the circuit). The accuracy of the measurement should be much larger than this influence so that it can be neglected. Otherwise one has to know the influence of the measurement. To get this knowledge sometimes a separate investigation is needed. The same applies to a calculation, because for the calculation a model of the circuit is made, that always neglects a lot of aspects of the real circuit.

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